Advanced Tactical Targeting Technology

DARPA Tech '97

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This briefing discusses a new initiative under the DARPA Tactical Technology Office: Advanced Tactical Targeting Technology (AT3).

Advanced Tactical Targeting Technology (AT3)

Purpose

Develop and Demonstrate Enabling Technologies for a Cost Effective Tactical Targeting System for Lethal Suppression of Enemy Air Defenses (SEAD)

- Target Generic Shoot-to-Coordinate Weapons for Precision Kill
- On-Demand Targeting with Flexible Engagement Tactics
- Exploit Opportunistic Collectors within Line-of Sight of Emitter
- Deploy Affordable Collection Packages on Multiple Host Platforms

Goal

- Accuracy / Timeline Sufficient for PGM Weapon Delivery
- < $250 K / AT3 Module

Warfighter Benefit ➡ New CONOPs for Killing SAMs

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AT3 will develop and demonstrate technologies which will radically improve today's capability to target weapons against enemy air defense systems for lethal Suppression of Enemy Air Defense, or SEAD.

The overall concept is

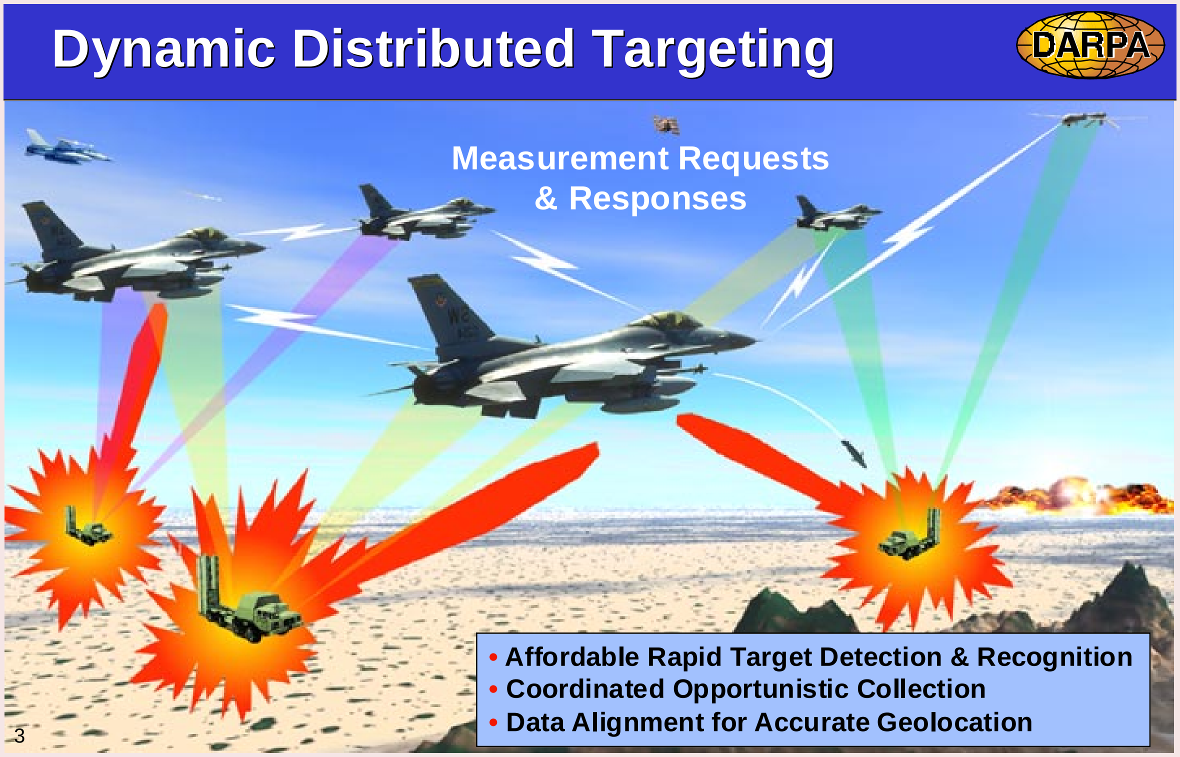
First, target generic shoot-to-coordinate weapons without requiring that a weapon seeker be able to detect, recognize and home on the target. Therefore, unlike today's SEAD weapon, the HARM, targeting will be effective regardless of whether the target emitter stops emitting, as is often the case.

Second, use opportunistic collectors. Don't require or desire dedicated platforms flying in highly constrained formations with considerable prior coordination.

Third, use host platforms. If the targeting systems can be deployed widely as adjunct sensors on as many platforms and types of platforms as possible, then anyone in line of sight of the target can participate in the targeting solution. This not only increases the accuracy of the solution, but also provides operational flexibility.

The performance goal is to achieve accuracy sufficient to target Precision Guided munitions to within their lethal envelope and to do so within a timeline sufficient to preclude mobile Air Defense Units from moving outside that envelope.

This capability for high confident lethal SEAD with relatively unconstrained tactics will enable a radically new operational concept for suppressing enemy air defenses.

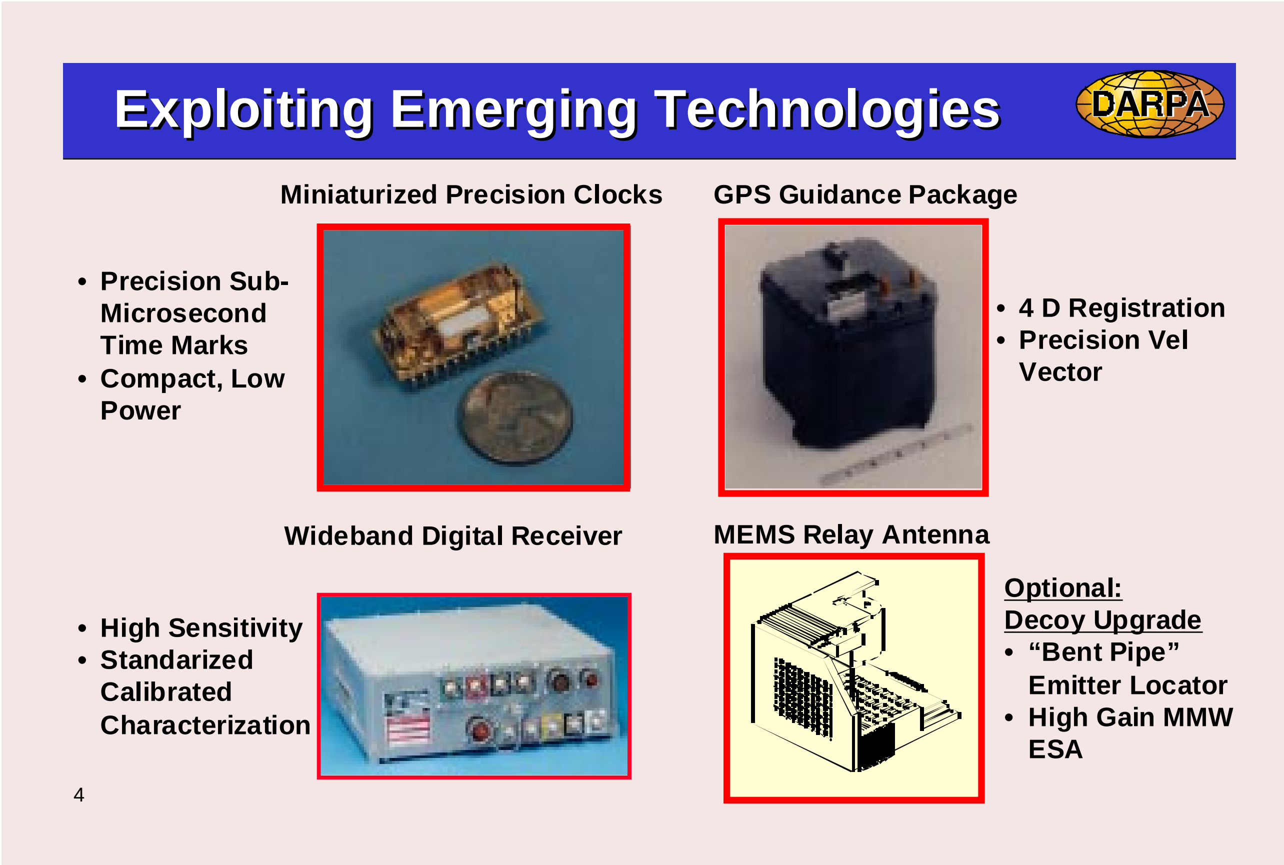


This chart illustrates the general concept and associated issues.

AT3 receiver/processor packages will be carried by various aircraft in the operational region, be they manned aircraft, UAVs, Miniaturized Air-Launched Decoys (MALD), and possibly other platforms.

Any one of these platforms (or an outside source) may detect an emitter and classify it as a potential target. This initial collector broadcasts requests for cooperating platforms in the region to provide measurements on the emitter. These other platforms may be at any geometries relative to the target. As they will most likely not be in the emitter's main beam, these "supporting" platforms must make measurements at very low signal levels. Because of the high accuracy requirements, the measurement errors due to noise must be reduced by processing (since we can't put big new high-gain antennas on tactical aircraft). Collectors return measurements on intercepted pulses, to include Time of Arrival, Frequency of Arrival and the collector's navigation position and velocity vector. Depending on the processing concept employed, collectors may return sampled signal waveform. These returned measurements are processed, either at the initiating collector or at some other processing node.

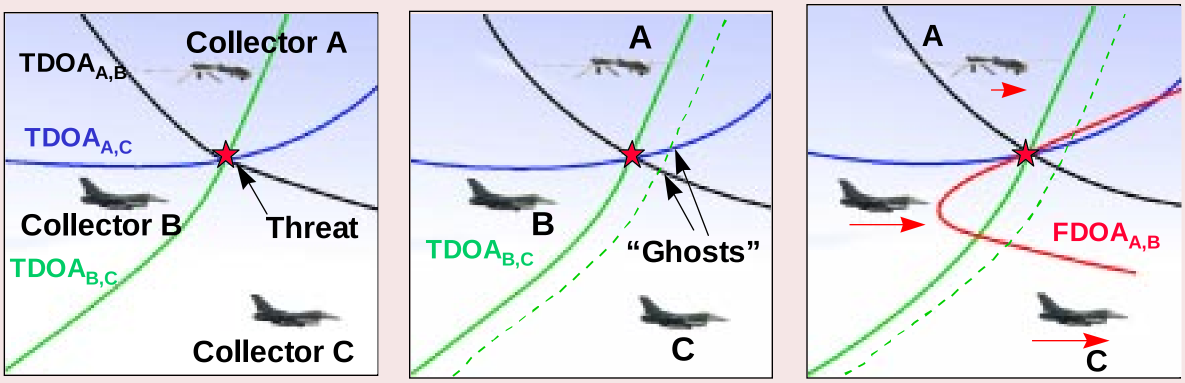
Time Difference of Arrival (TDOA) geolocation requires that pairs of measurements be taken on the identical emitted pulses. Given the very limited bandwidths of current and programmed tactical datalinks, receiver dwells must be coordinated and selected measurement data exchanged efficiently for timely processing. To aid in reducing communications data loads and minimizing bias errors in associating the measurements from widely dispersed collectors, precise spatial temporal alignment among the collectors will be needed.



The technology thrusts which enable this new concept are shown here. These include

- Space-Time Reference system technologies for precise, real-time alignment of collector location, velocity vector and timing. The GPS Guidance Package (GGP), a precision GPS/INS, and a precision clock can provide the needed 7D (time, position and velocity) registration of Air Battlespace.
- Microwave receiver and signal processing technologies for the needed sensitivity, measurement accuracy and data association and alignment in relatively unconstrained geometries, including in low Signal-to-Noise conditions when one or more collectors are in the emitter's sidelobes.
- MEMS (Micro Electro-Mechanical System) technologies. An interesting variant of AT3 involves a single strike aircraft deploying decoys such as MALD (Miniaturized Air-Launched Decoy) with GGP packages and simple RF repeaters. For this concept, MEMS technology is being pursued for wideband, high gain data relays.

AT3 Uses TDOA for Fast, Accurate, Passive Geolocation



TDOA with 3+ collectors provides near-instantaneous emitter geolocation

But, ambiguities can occur if pulses are misassociated

Can use FDOA to resolve ambiguities (and refine accuracy)

TDOA = Time Difference of Arrival **FDOA = Frequency Difference of Arrival**

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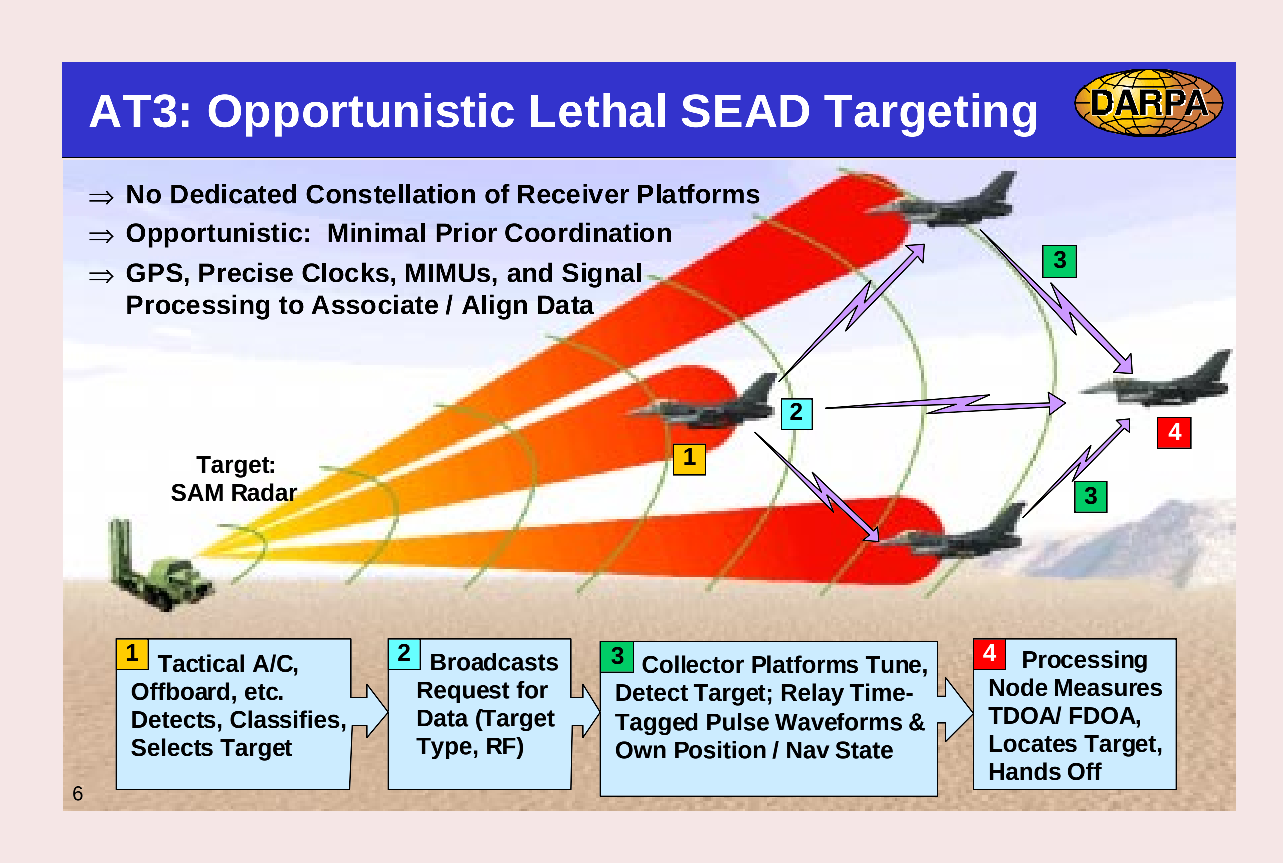
- The AT3 concept employs passive RF multiplatform geolocation; namely, Time Difference of Arrival (TDOA), supplemented with other techniques for ambiguity resolution. Because the system measurements will be quick and accurate, unlike single passive platform target location techniques, it will be possible to shoot to the target coordinates despite target emitter shut-down or mobility.
- TDOA technique requires 3+ platforms with coordinated measurements (panel one): Each collector measures the Time of Arrival of an emitted pulse. For each pair of collectors (e.g., A and B), the TDOA (tB-tA) correspond to possible locations along a hyperboloid. With three collectors, the hyperboloids intersect at the emitter.
- This intersection, however, depends on each TDOA measurement being taken on the same transmitted pulse. If different transmitted pulses are used to measure TDOA, then we have the situation shown in panel two. Here, a pulse received by B has been associated with an earlier pulse received by C. This false TDOA corresponds to the dashed hyperboloid, which intersects at erroneous, "ghost" locations.
- Integrating additional techniques (e.g., Frequency Differences of Arrival (FDOA) or angle of arrival measurement) can assist in eliminating ghost solutions, as well as enhancing measurement accuracy. The third panel shows how two platforms can resolve location using TDOA plus FDOA. Here, the same pulses used to measure TDOA are exploited for the difference in Doppler frequency, given the collectors' velocity relative to the threat. The difference in frequency received by Collectors A and B corresponds to possible emitter locations on the red locus. This will intersect with the TDOA curves at the correct emitter location, but will not intersect at the "ghost" locations.



Opportunistic and flexible target geolocation emphasizes

- No dedicated constellation of receiver platforms.
- A minimum of required prior coordination.
- Reliance on GPS, precise clocks and signal processing to associate and align data.

A procedural sequence of the AT3 targeting process is shown here:

1. A collector (fighter, UAV, external) detects/classifies a target emitter.
2. It broadcasts requests (target type/ RF parameters) for emitter collection from other collectors.
3. Responding collectors in the area—which may include MALD decoys—automatically tune; relay pulse Times of Arrival (TOAs), received RF, other parameters and own position and velocity.
4. A Processing Node measures the multiply collected TDOA/FDOA data reports to locate and target.

AT3 Technical Challenges

DARPA

Affordable Rapid Target Detection and Recognition

- Wideband, High Sensitivity Affordable Receiver
- Pulse Sorting & Target Classification

Data Alignment for Accurate Geolocation

- Precise Position, Time and Velocity Alignment
- Pulse Train and Pulse Ambiguity Resolution
- Signal Waveform Matching at Low SNR

Coordinated Distributed Collection

- Employ Narrowband Tactical Data Channel(s)
- Adaptive Protocols to Minimize Latency in Coordinating Dwells
- Data Packet Management to Minimize Reporting Latencies

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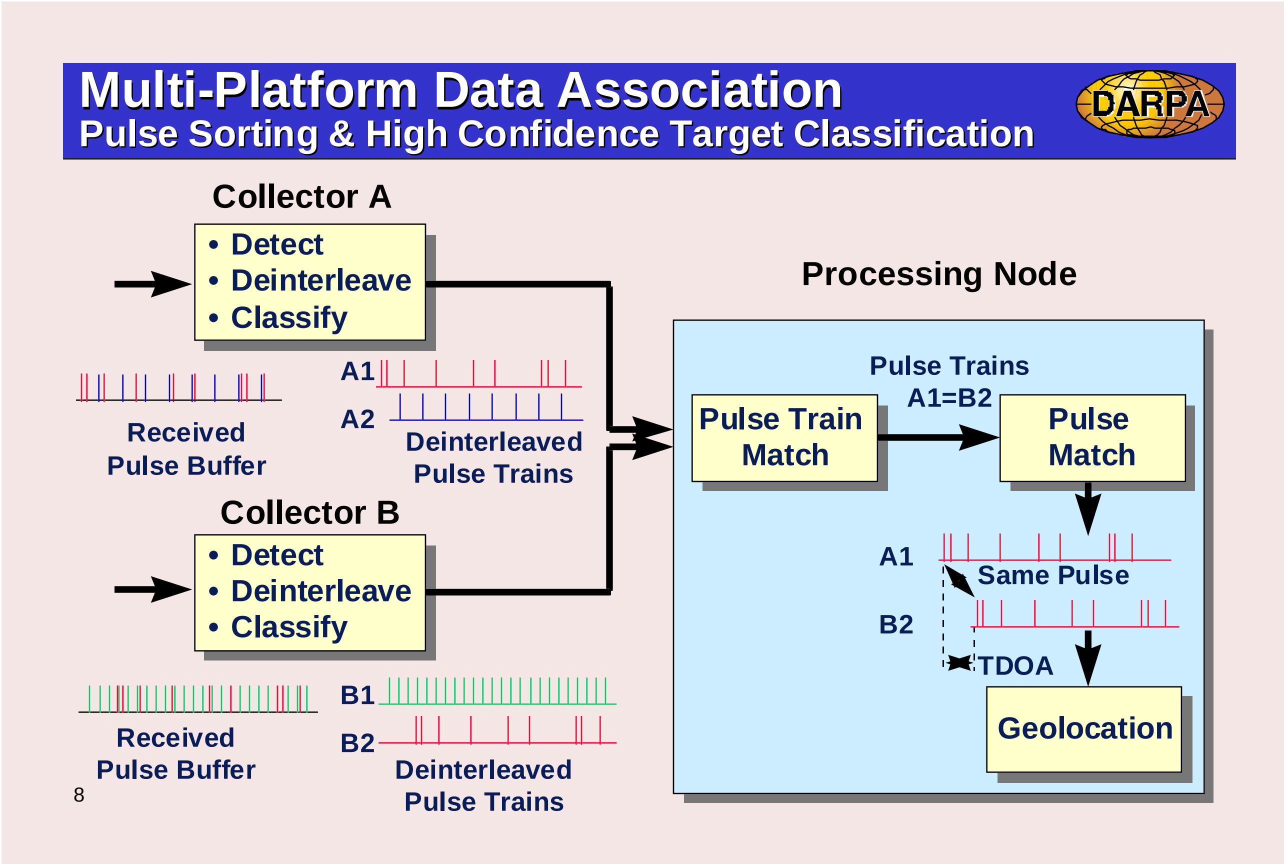
AT3 Technical Challenges include

- Affordable rapid target detection and classification, by collectors to achieve:
  - –Wideband, high sensitivity, “standardized” collector receivers, for rapid unconstrained-geometry emitter detection
  - –High confidence target classification processing
- Emitter data alignment for accurate geolocation by the Processing Node needs:
  - –Precise position, time and velocity alignment: GPS, Clock, IMU
  - –Pulse train and pulse association/ambiguity resolution processing
  - –Signal waveform matching at low signal to noise ratios (employing 2D cross-correlation algorithms in a high-speed array processor)
- Coordinated distributed collection by C3 needs:
  - –Protocols to coordinate dwells (same pulses collected by all)
  - –Communication management to minimize reporting latencies

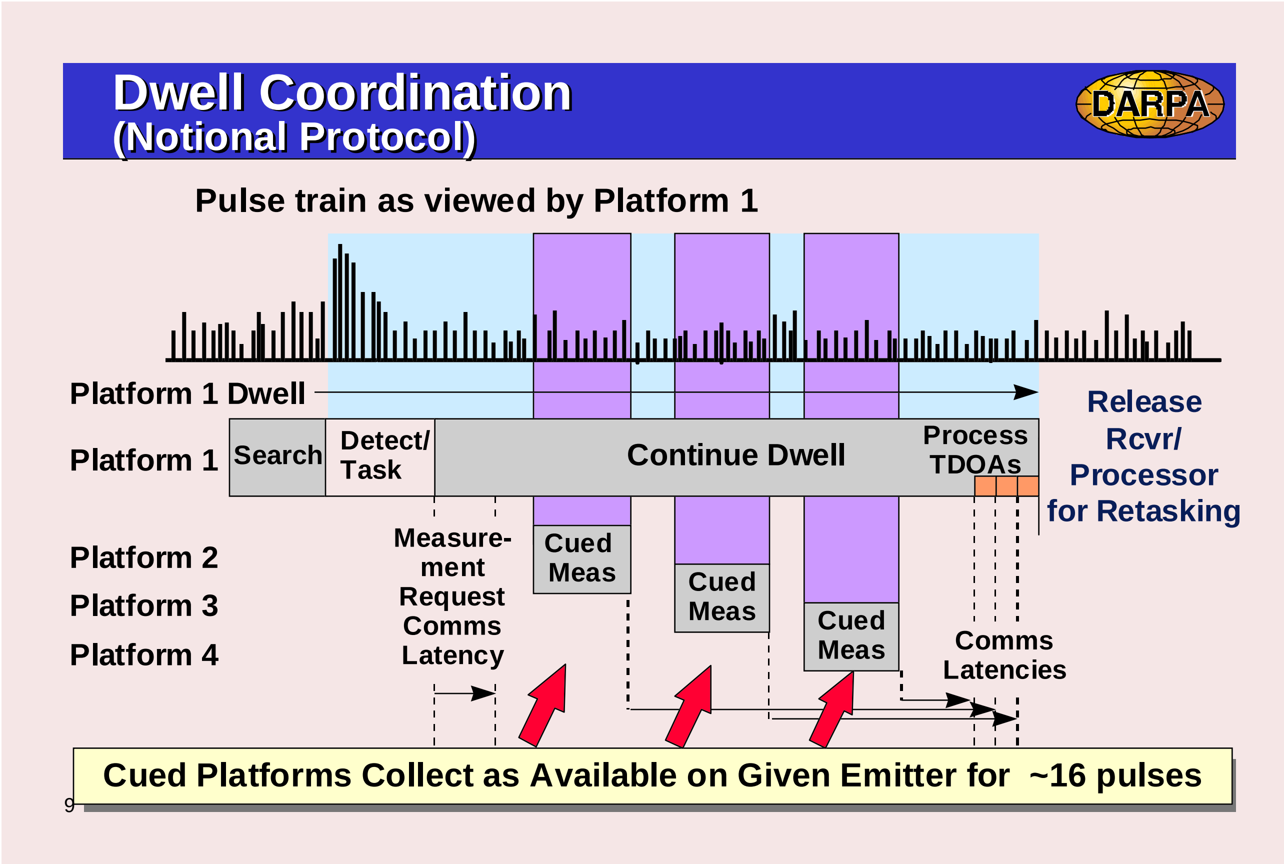
Example technical challenges are discussed in the next two charts.



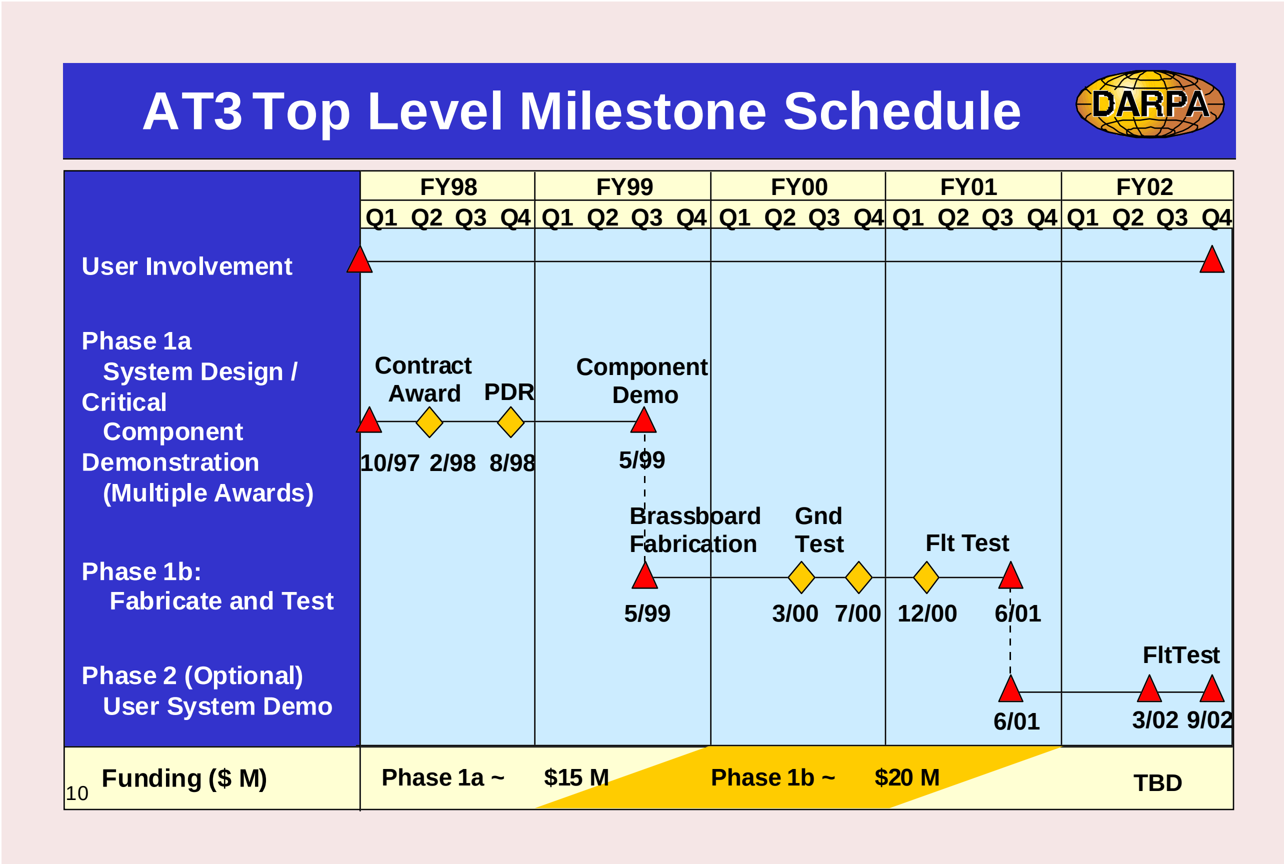
TDOA Geolocation requires that all associated collection measurements be resolved to the same target and the same pulse(s). The unconstrained geometries and open collection constellations which will be typical of AT3 missions increase the need for solutions which eliminate pulse misassociations. AT3 will utilize advances in digital signal processing, data fusion, and space-time reference technologies to resolve these problems.

DARPA is looking for the US Defense Industrial technology base to develop the AT3 system architecture and distributed processing methodologies needed to successfully accomplish the functional needs shown by example in this chart. The resulting tactical emitter collector packages must be affordable with low host burden to accomplish the necessarily wide spread deployment on theater tactical airborne assets. Furthermore, AT3 must manage its data compression and processing load distribution together over a low information rate broadcast type communication network in order to achieve rapid response times and control data latency. All of this must be accomplished in dense threat operating environments.

Major advances in emitter focused data fusion algorithms along with real time distributed processing control will be required. The early phase of AT3 development will quantitatively assess, by means of computer simulation, the architectural tradeoffs between collection algorithms, processing, throughput, and delay. Advanced digital receiver technologies will be reviewed and paired with precision 7D registration space-time technology (GPS, clock, INS, etc.) to determine achievable target location error (TLE).



This chart takes the distributed AT3 problem one layer deeper "into the onion." It is meant to exhibit conceptually some of the time line activity and coordination required within an AT3 collection network. From notional constructs, such as this, the AT3 development will use quantitative tools for evaluating event probabilities and averaged response values for pertinent choices of system parameters. Through system parametric trades, we expect to identify and determine the subsystem performance values and maintain an on-going AT3 system error-budget spread sheet throughout system development.



AT3 is a DARPA led effort with Wright Lab participation. Multiple contract awards will be made for Phase 1a, system design and critical component demonstration. A single contract option will be executed to proceed into Phase 1b system fabrication and flight test.

This program has been coordinated in the DOD:

- Operational User participation will be extensive throughout the program to insure the revolutionary new CONOPS are viable. A potential User system demonstration, Phase 2, is being considered for funding by the Services in the out years.
- AT3 is being tracked by the Joint DARO, NRO and NSA Interoperability Task Force (e.g., AOITF) as the next generation tactical platform precision SIGINT targeting capability.

The transition strategy is based on retrofit to existing aircraft with minimum vehicle modification either via existing pod retrofit or through utilization of already installed antenna apertures. Also insertion into new vehicles such a JSF, UAVs, and MALD will be pursued. As appropriate, other platforms will be investigated. Expected application transition customers include the Air Force, Navy and DARO.

To summarize my talk today, AT3 is a new DARPA effort to:

- Enable responsive, efficient precision targeting of threat air defense units.
- Bridges the gap from reactive suppression to preemptive destruction.
- Exploits tactical platforms (fighters, UAVs, decoys) for SEAD applications.